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Title: Data Challenges for Structural Health Monitoring of Electrical Machines

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Data Challenges for Structural Health Monitoring of Electrical Machines

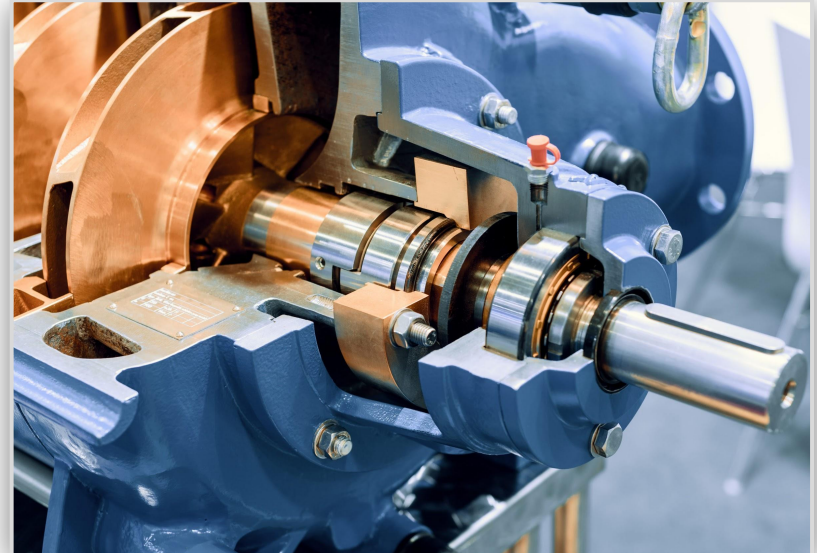
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Mentors:

Phillip Cornwell & Nick Lieven

Date: 8/12/2021



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I will introduce our project and talk about the results of tested filters.

Project Introduction

- Induction motors
- Problem overview/
motivation

Methods

- Adaptive Frequency
- Kalman Filter
- Spectral Subtraction

Future Work

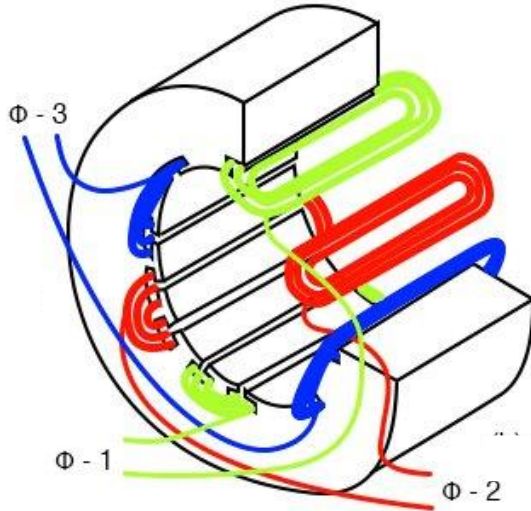
- Thresholding
- Motor decay



www.washingtonpost.com

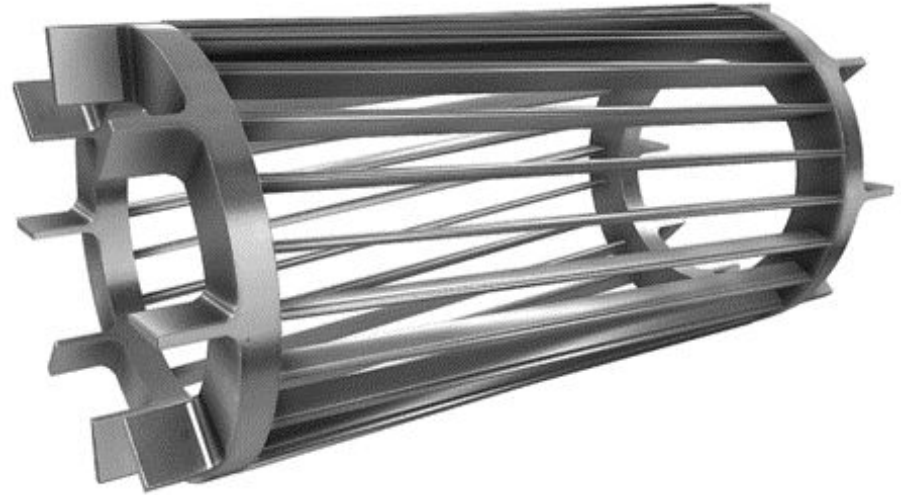
Induction motors (ID) consist of a stator and a rotor.

Stator of 2 pole ID



allaboutcircuits.com

Squirrel-cage Rotor



savree.com

Induction motor slip decreases with decreasing load.

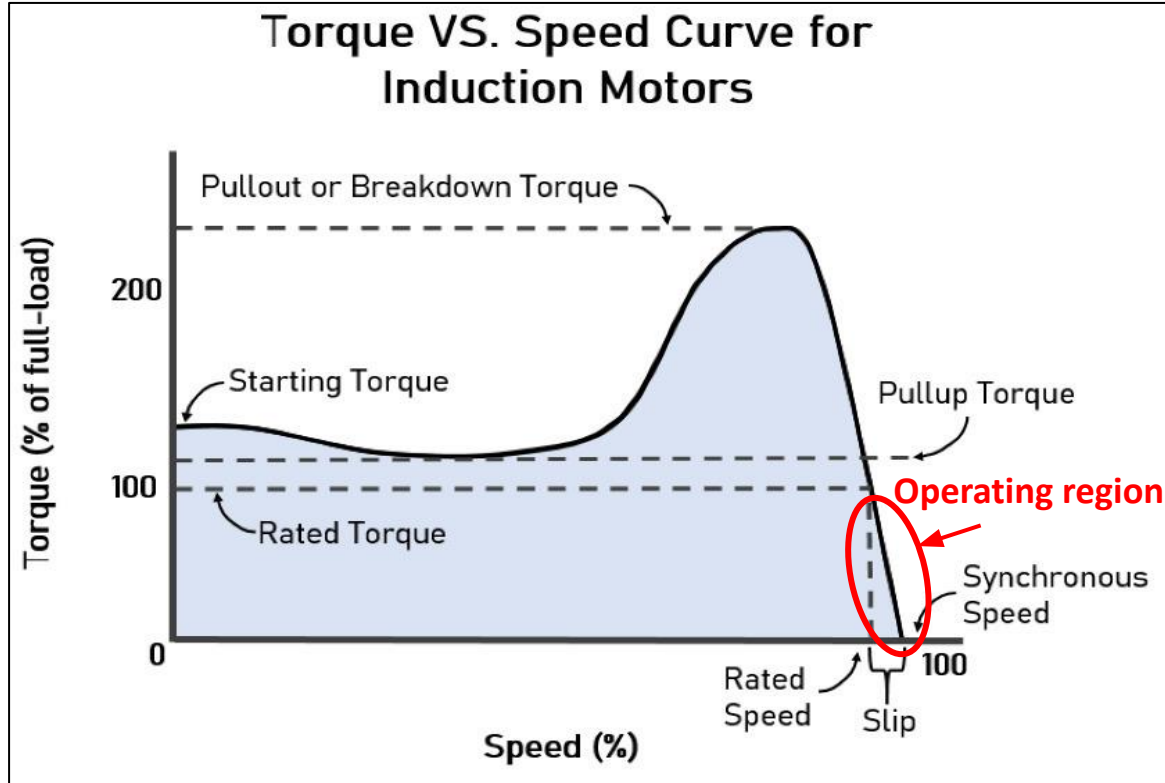


Diagram courtesy of Christian Cavallo

Slip

$$S = \frac{f_s - f_m}{f_s}$$

Mechanical Frequency

Synchronous power grid frequency

Rotor beam currents induce sideband frequencies in the stator current based on the slip frequency that increase in magnitude as rotor beams break.

$$f_b = (1 \pm 2ks)f_s$$

f_b = side-band frequency

$k = 1, 2, 3 \dots$

s = slip

f_s = synchronous frequency

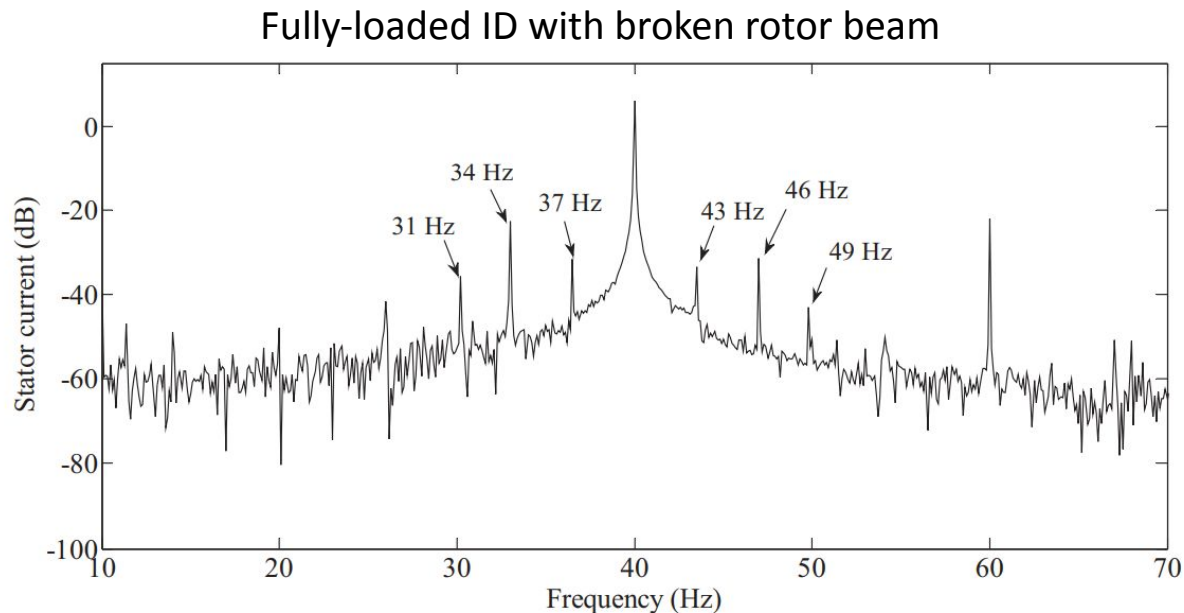


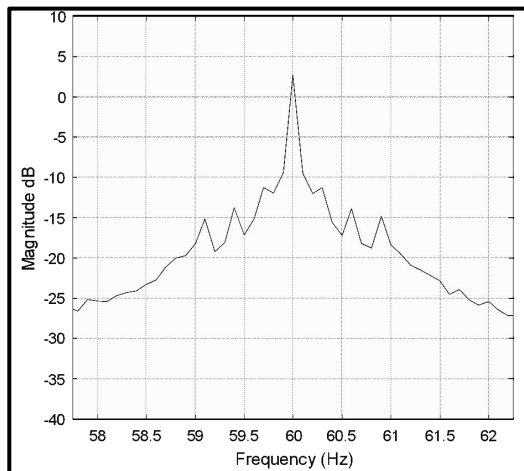
Figure courtesy of Purushottam Gangsar and Rajiv Tiwari (2018)

This talk will focus on removing closely coupled power grid frequencies in an effort to observe the true dynamic response signature of Induction motors.

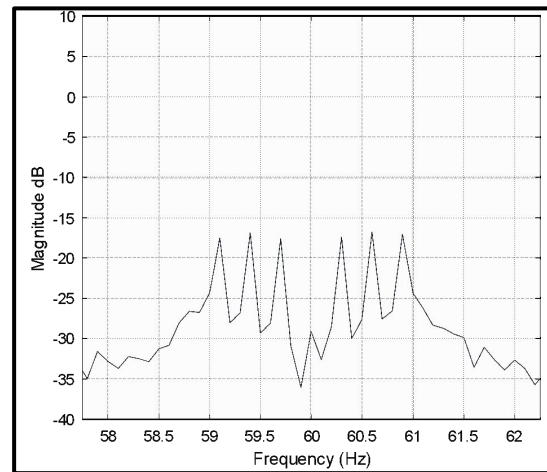


Broken rotor bars

Ying Xie, Jingpeng Guo, Peng Chen, and Zhiwei Li
(2018)

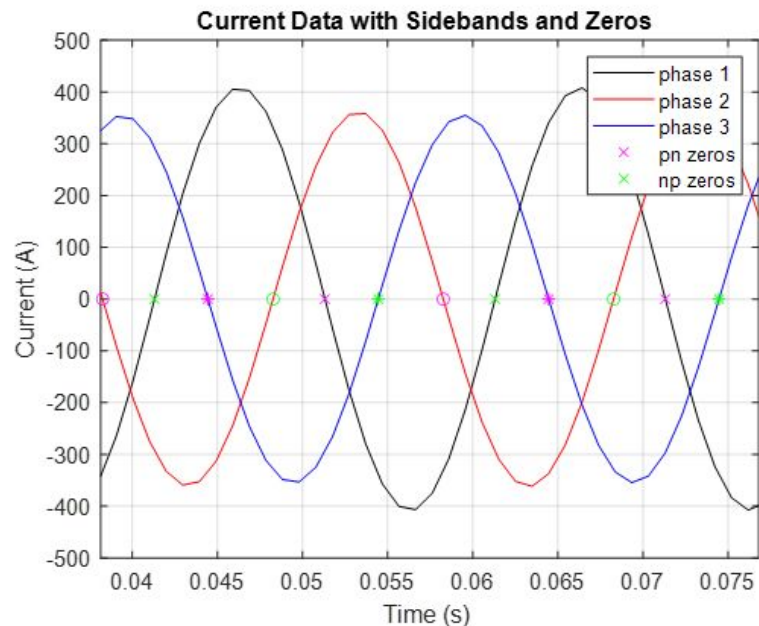


Simulated signal in Matlab

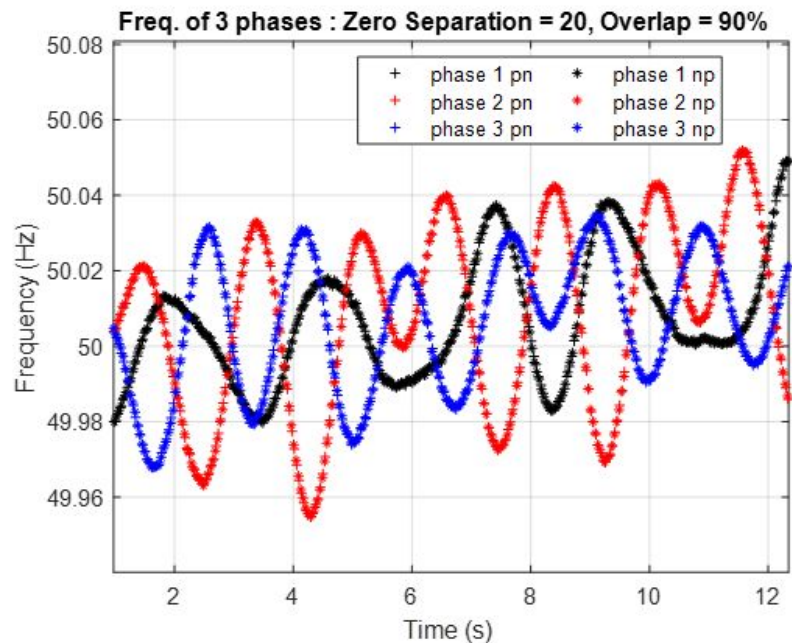


Simulated signal with 60Hz noise removed

Using the time difference between the zeros, we found the frequency as it changes over time for each of the 3 phases.

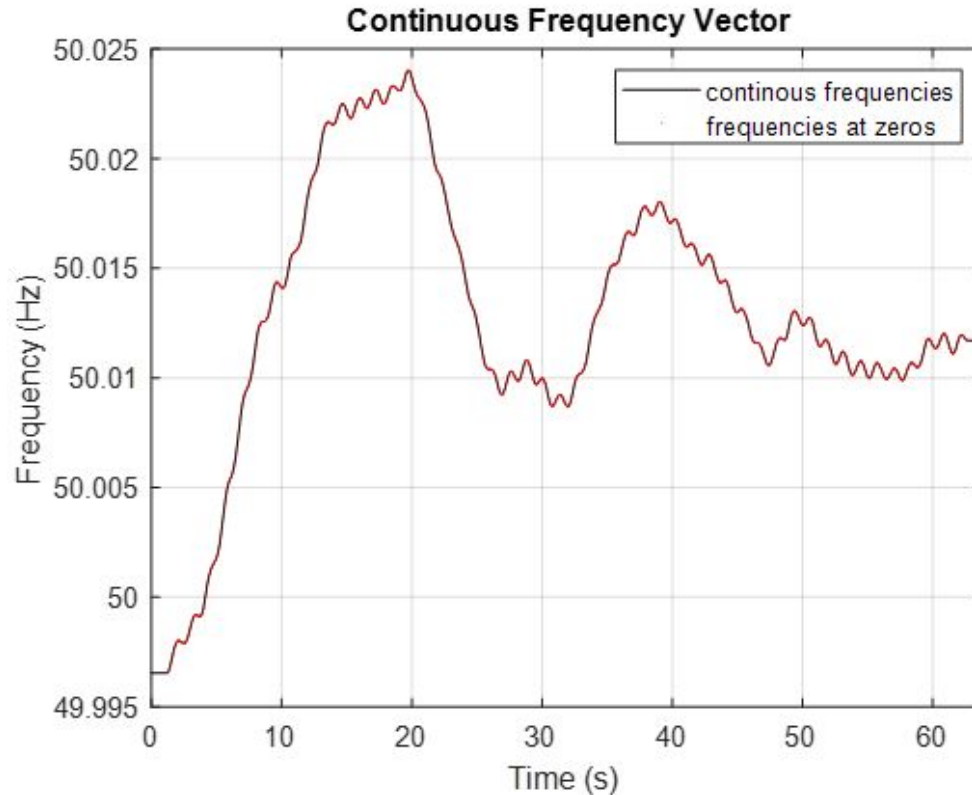


Three phases of the current data with six identical sidebands added to each

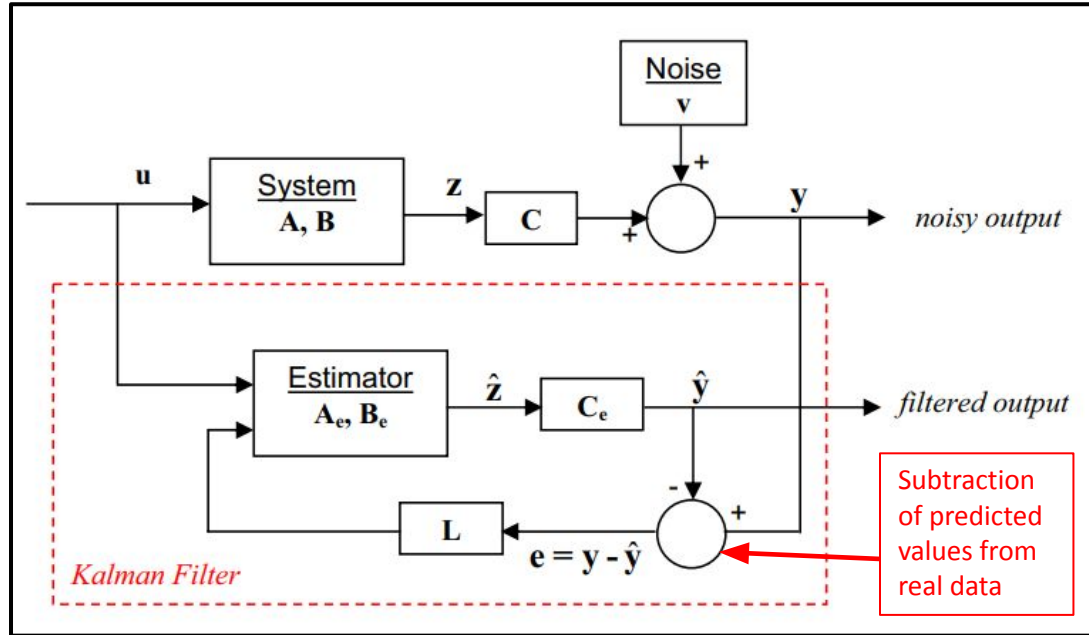


The frequencies of the three phases

The frequencies of the 3 phases were averaged to reduce the effects of sidebands on the instantaneous frequency.



Kalman filters use a model to estimate the output to a system that can't be directly measured.



$$\bar{x}_{i+1} = \underbrace{\begin{bmatrix} 2\cos(w_o) & -1 \\ 1 & 0 \end{bmatrix}}_A \underbrace{\begin{bmatrix} x_i \\ x_{i-1} \end{bmatrix}}_{\bar{x}}$$

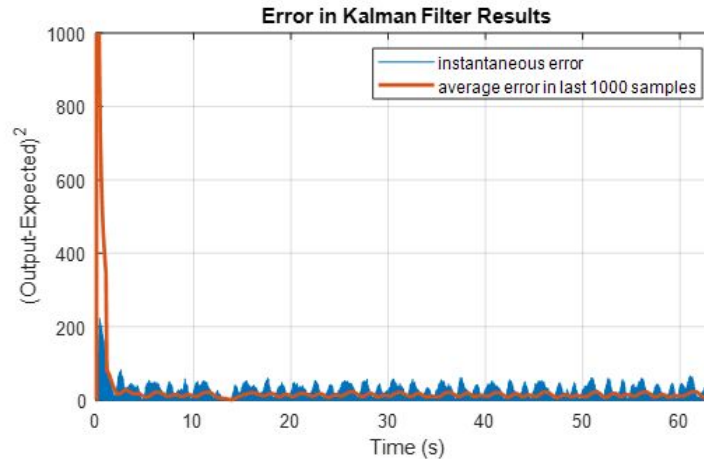
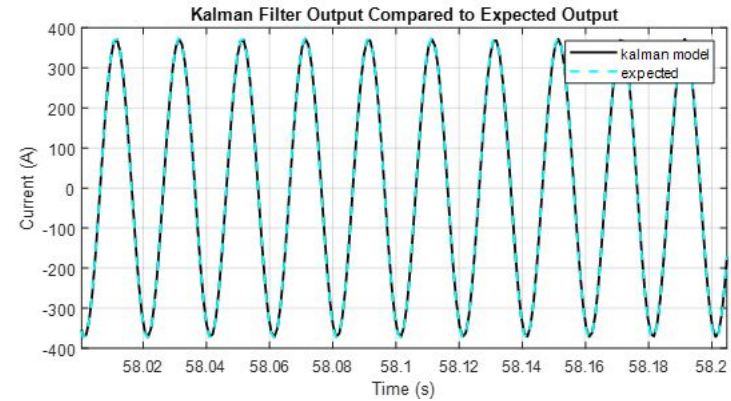
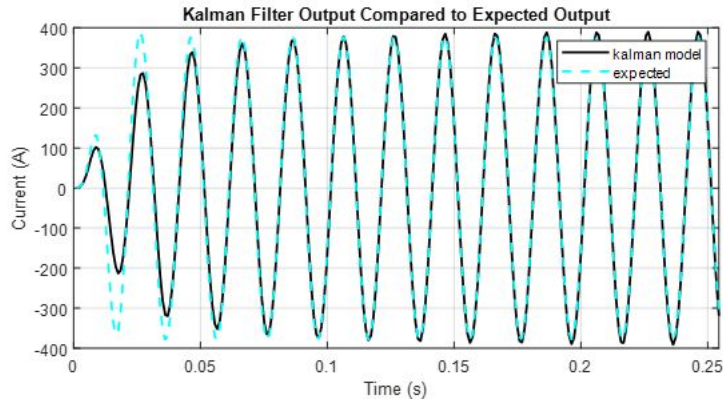
$$w_o = \frac{2\pi f_i}{f_s}$$

Instantaneous Frequency f_i
Sampling Frequency f_s

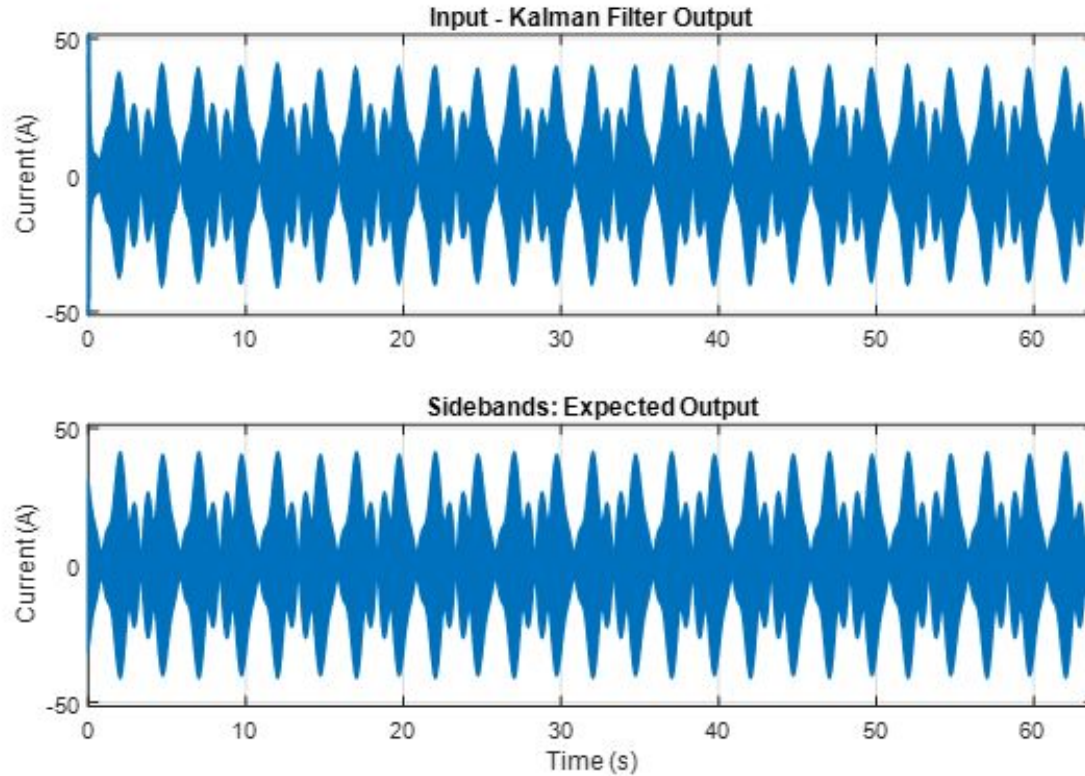
Kalman Filter block diagram

Diagram courtesy of Juan R Carrion and Billie F. Spencer, Jr.

The Kalman filter rapidly synchronizes with the expected output.

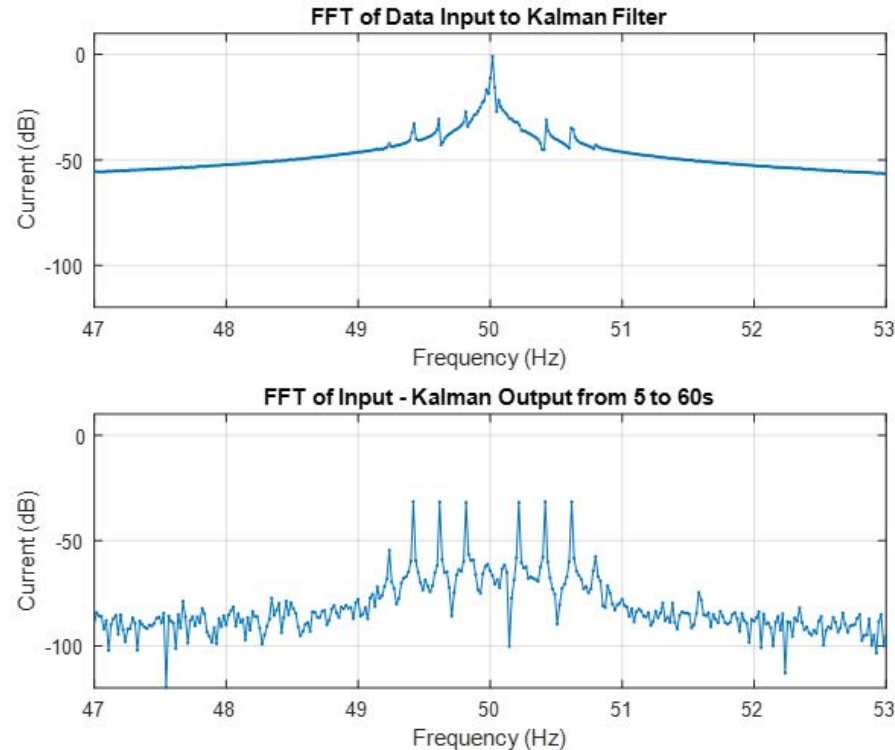


The sidebands were recreated using spectral subtraction.



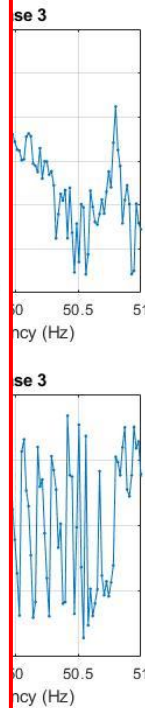
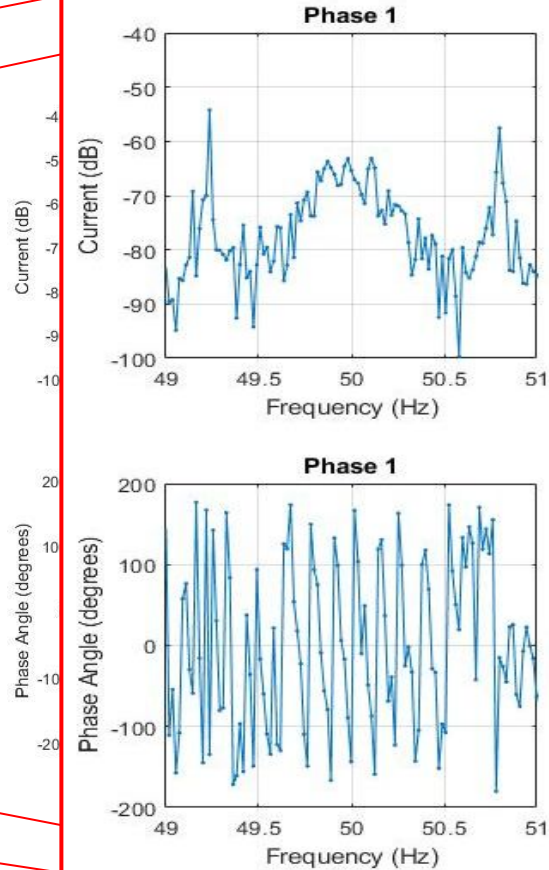
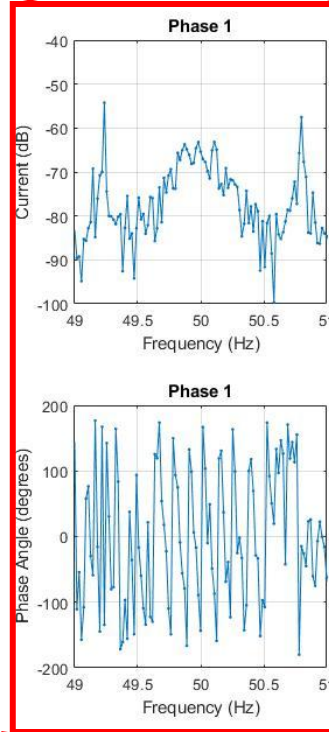
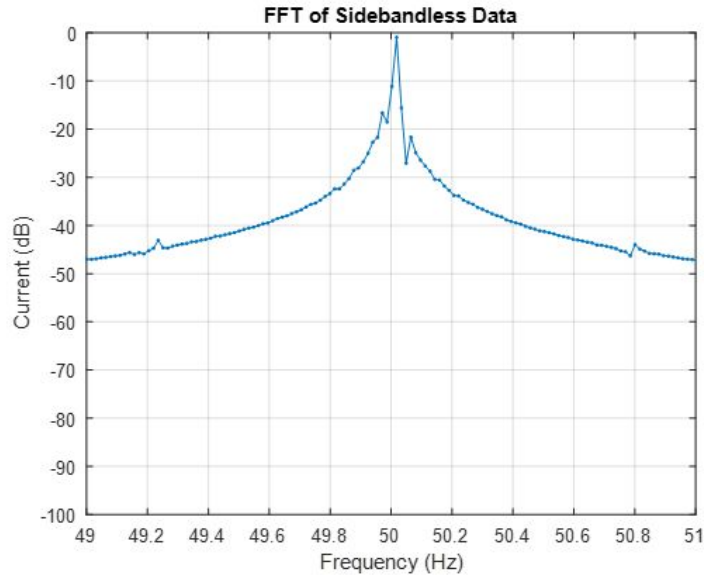
Sidebands Kalman Filter output against the expected output

The frequency domain shows the reduction in magnitude of the power grid frequency the Kalman output was subtracted out.

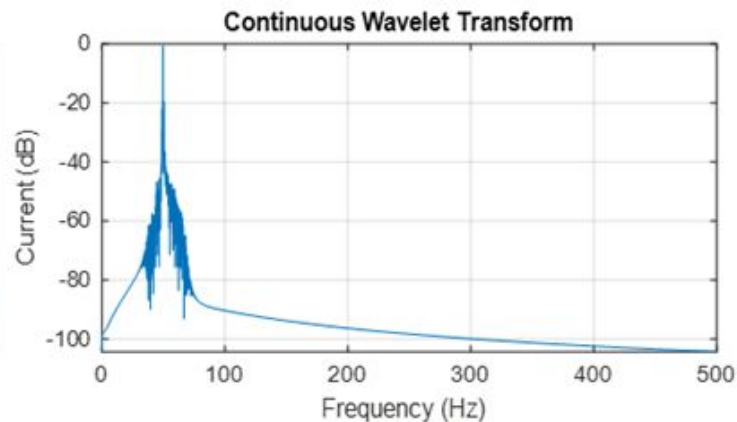
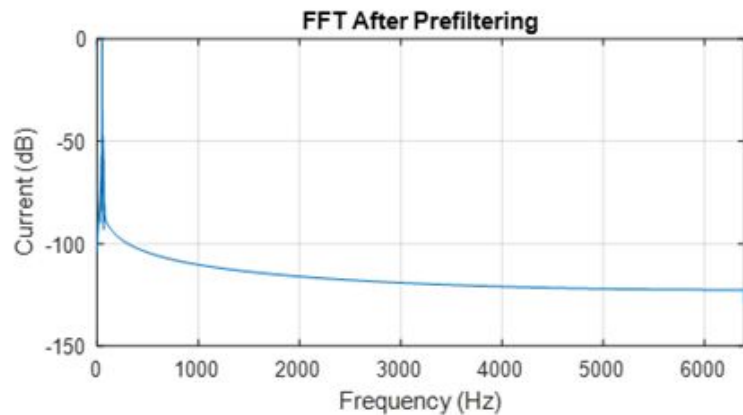
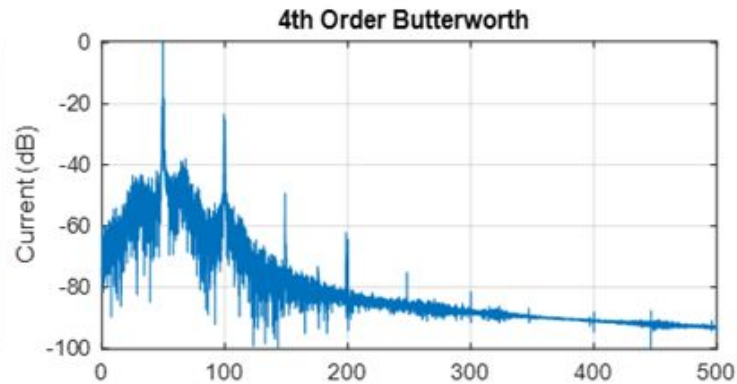
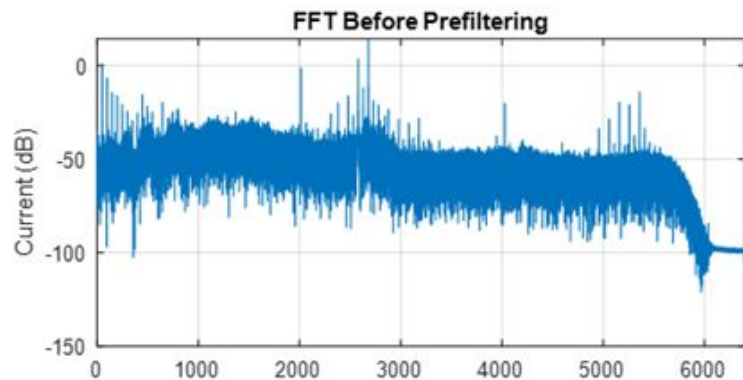


FFT of the measured data against the FFT of the Kalman filter output

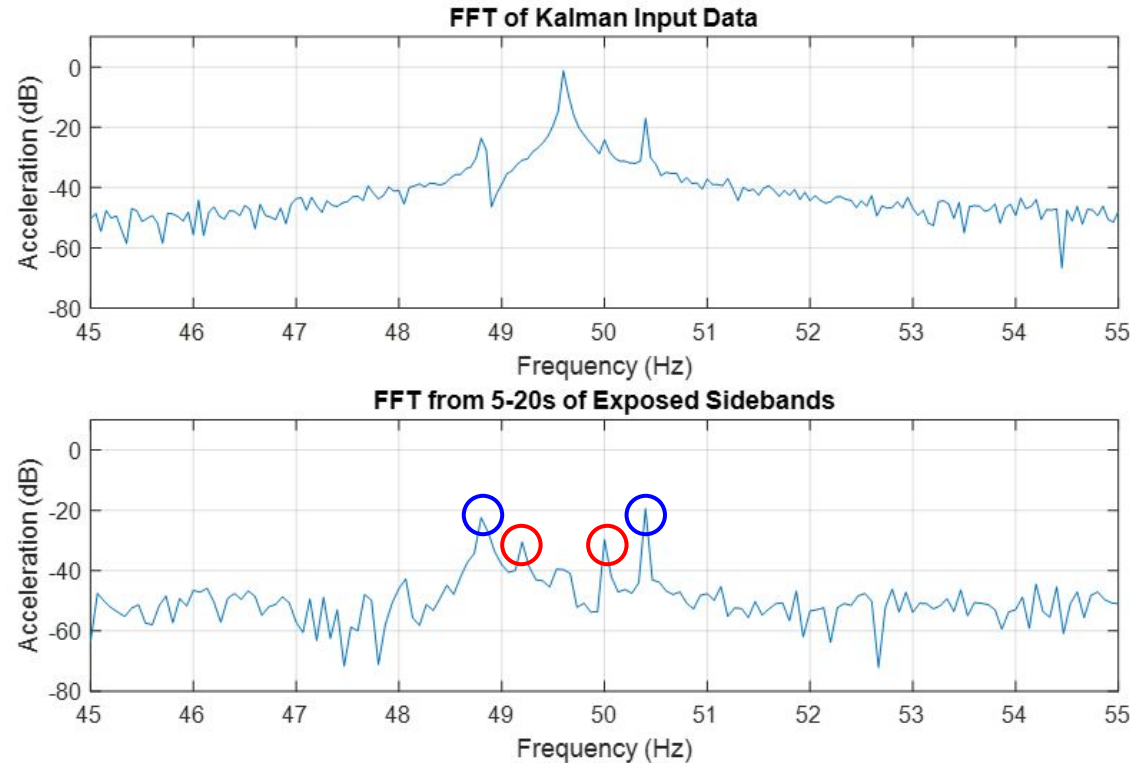
Kalman filtering also reveals important data about the sidebands in healthy motors.



The Continuous Wavelet Transform is an alternative to a Bandpass IIR filter used in the analysis of the acceleration data.



Analysis of the acceleration data reveals 4 sidebands around the slip frequency.



$$f_{sidebands} = f_r \pm (f_s - f_r)p$$

f_r = rotor frequency

f_s = current frequency

p = # poles

Unknown Origin

We introduced our project, talked about our methods and discusses results and future research that can be conducted.

Project Introduction

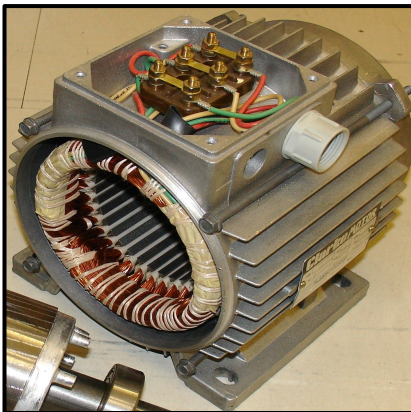
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Questions?

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